BUILT FOR
TODAY.

DESIGNED FOR
TOMORROW.

A Knowledge-Centric Approach for Complex Systems

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ENGILITY
Your Mission. Our Commitment.

Dr. Chris R. Powell, MBA

- 31 years experience in systems, hardware, and software engineering
  - 17 years in commercial development
    - IBM, Supercomputer Systems, Inc., Network Systems Corp., StorageTek, Sequent Computer Systems, and several start-ups
    - Network, I/O, Subsystem, CPU, Interoperability
    - Operating System, Subsystems, NetComm Stack
    - Secure Systems Engineering
  - 14 years in Federal Government consulting
    - Depts of Defense, Treasury, Justice, Energy, Homeland Security, Commerce
    - System of Systems Engineering, Software Engineering, Software Reliability, Systems Architecture, Interoperability, System Assurance, Security Engineering
- Research – Technical Systems Management, Philosophy of Knowledge, Innovation
  - Organizational and individual dynamics involved in complex decision-making and engineering especially focused on tacit knowledge.
  - Goal is to improve frequency and magnitude of success with complex investment.

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SoS Problems and Solutions

- Basic Problem in System Acquisition
- New Thing: Looking at Complex Systems as Socio-Technical
- Solution: Knowledge-Centric Approach
  - New SE/PM “V”
  - Architecture, Models, Management
- Complex Systems Engineering Framework (CSEF)

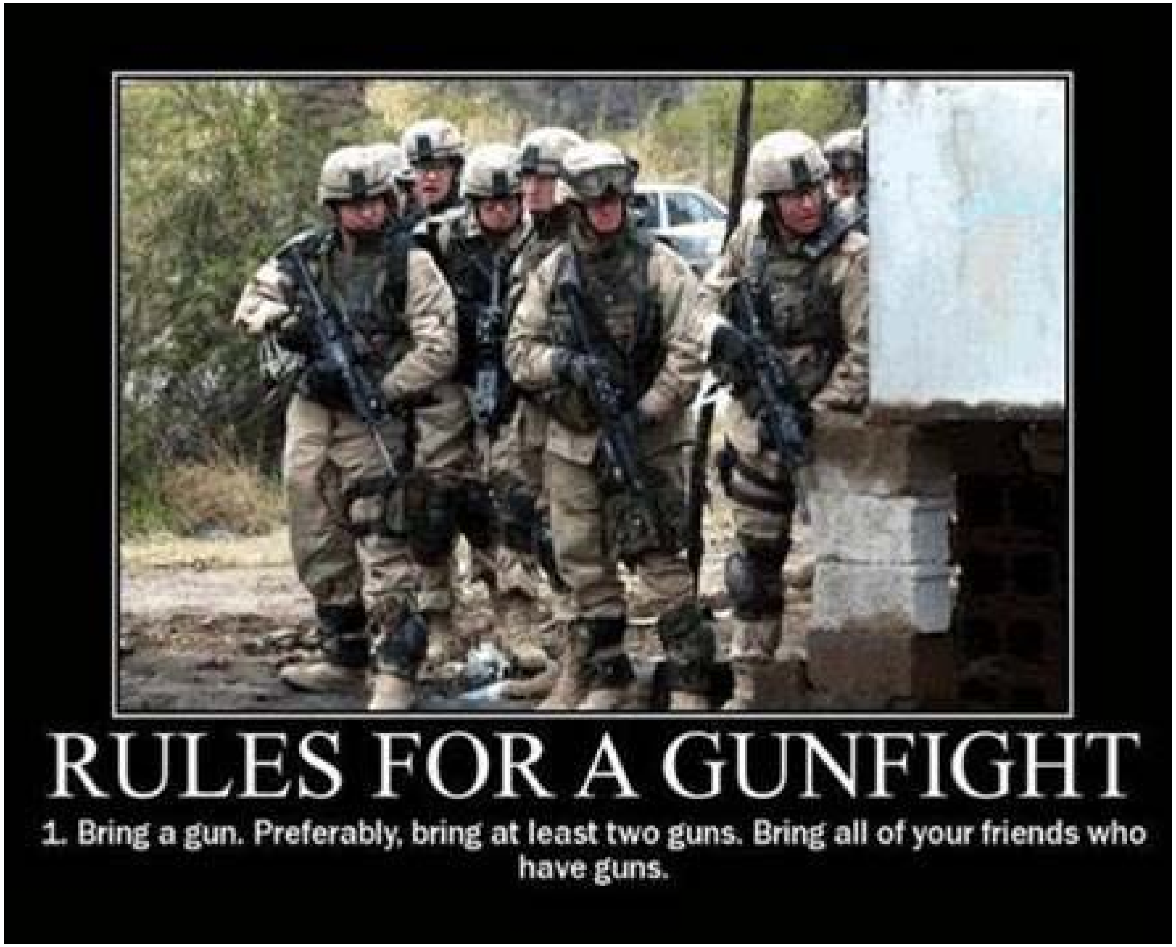
Basic Systems Acquisition Problem

Tension Between Complexity & Speed

- Increasing system complexity
  - Distributed users
  - Distributed data
  - Distributed computation
  - More analytic
  - More synthetic (data → information → knowledge)
- Increasing acquisition speed
  - Years…
  - …to months…weeks…days…

Reconcile complexity, identify solution, and achieve rapid fielding of continuously upgradeable system

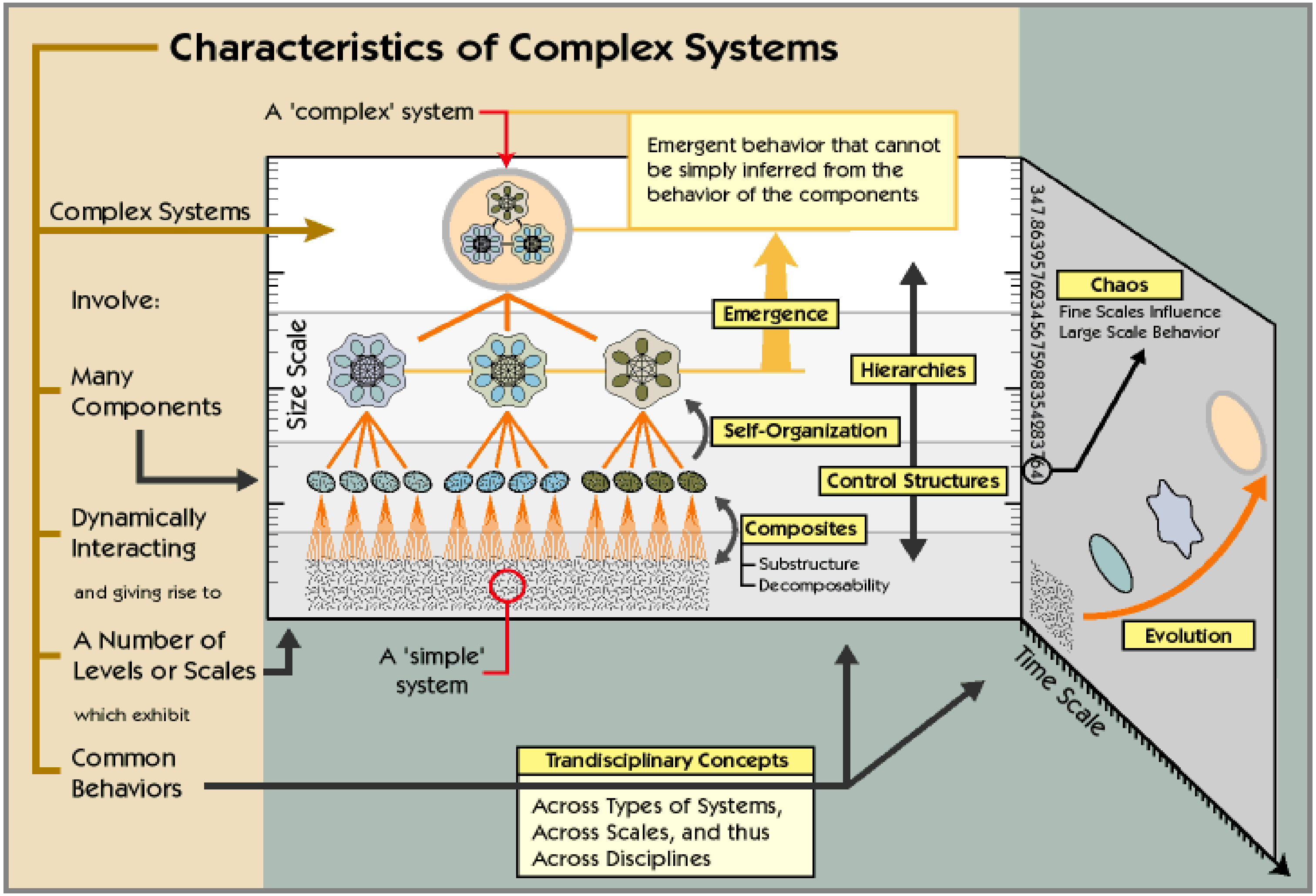
Bringing All Of Our Friends



Our SoS gunfights now require all on deck:

Need Force Multiplier

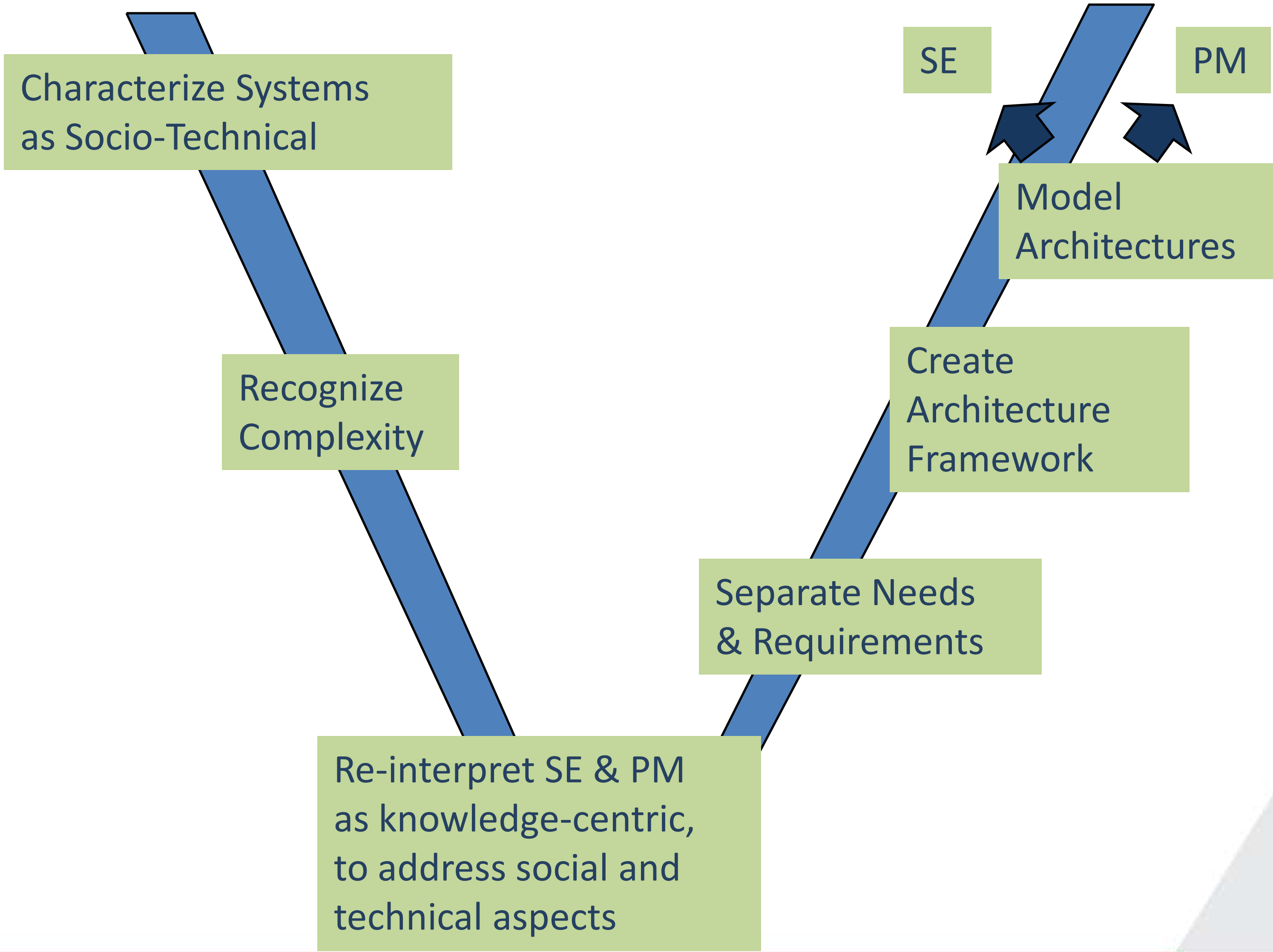
What is a Complex System?



Bar-Yam, Yaneer, "Engineering complex systems: multiscale analysis and evolutionary engineering," in Braha, Dan, Ali A. Minai, and Yaneer Bar-Yam. *Complex Engineered Systems*. Cambridge, Massachusetts: Springer, 2006 [Bar-Yam 2006]

Complex – dynamic, emergent. Complicated – many moving parts.

Basic Solution Approach: New SE/PM "V"



Characterize Systems as Socio-Technical Systems

- Technical system – system-as-created
  - *Analytic* - problem decomposition
  - Tradition of Natural Science: Quantitative, Objective
  - Responsive to requirements through Explicit and Embedded knowledge
- Social system – system-as-intended, system-as-used
  - *Synthetic* – socially-constructed, emergent
  - Requires Social Science: Qualitative, Subjective
  - Focuses on Felt needs, Tacit knowledge

Typical System Problem Today

- System & Software Engineering (1 SOW section):
  - Design & Development
  - Architecture Development
  - IT Service Management Implementation
  - Enterprise Application/Services
  - Web Application Design & Development
  - Human/Computer Interaction
  - System/Software Integration
  - Modeling & Simulation
  - Information (Knowledge) Management Services
  - Engineering & Technical Documentation
  - Legacy System and Data Migration
  - Development Toolkit Support

Customers "want it all" – better services across more complex business model with advanced technologies: Requires complete social and technical approach

Solution Factor: Knowledge-Centric Approach

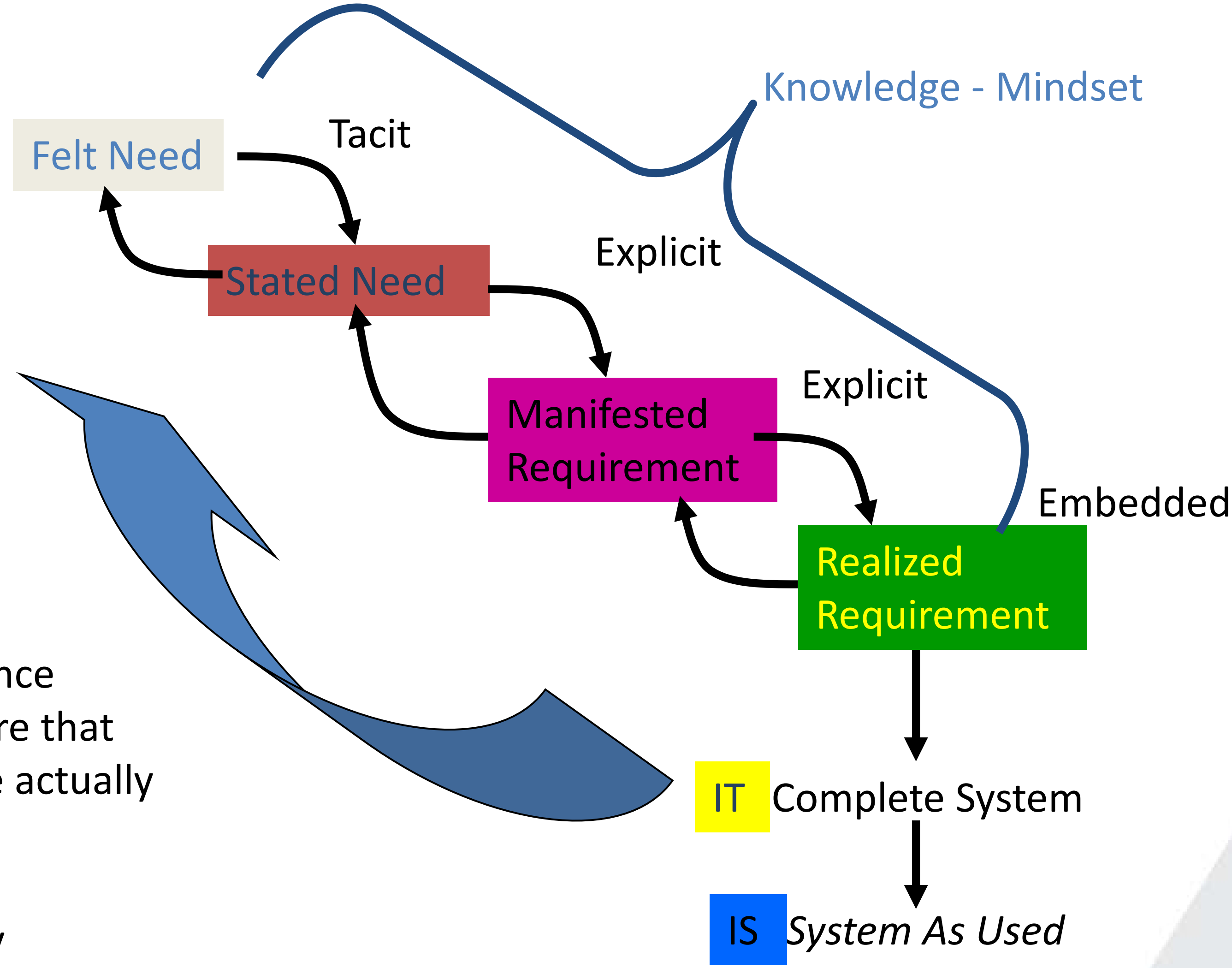
- Notion: Expedite time-consuming acquisition steps by providing and ensuring the following, starting early in the lifecycle:
  - **Rigorous recording of assumptions**, parameters, constraints, and other information through models, attributes, and metadata
  - **Rigorous correspondence of artifacts** across lifecycle steps/phases/etc. through common program taxonomy and ontology (e.g., model framework and metadata)
  - Quick, comprehensive **testability** of assumptions through simulation
  - **Simultaneous, early, and ongoing** consideration of engineering and program design issues to ensure risk prevention

How to Implement a Knowledge-Centric Approach?

- New acquisition model
- Architecture-driven SE & PM approach
- Visualization of dynamic, multiple system dimensions in context (social and technical)
- Modular, component-oriented design to enable system portability, extensibility, and address dynamic requirements
- Need to involve multiple COI/COP throughout system lifecycle – continuous dialog
- Need to enable system adaptability and flexibility – to a series of unknown (and perhaps unknowable) and new requirements

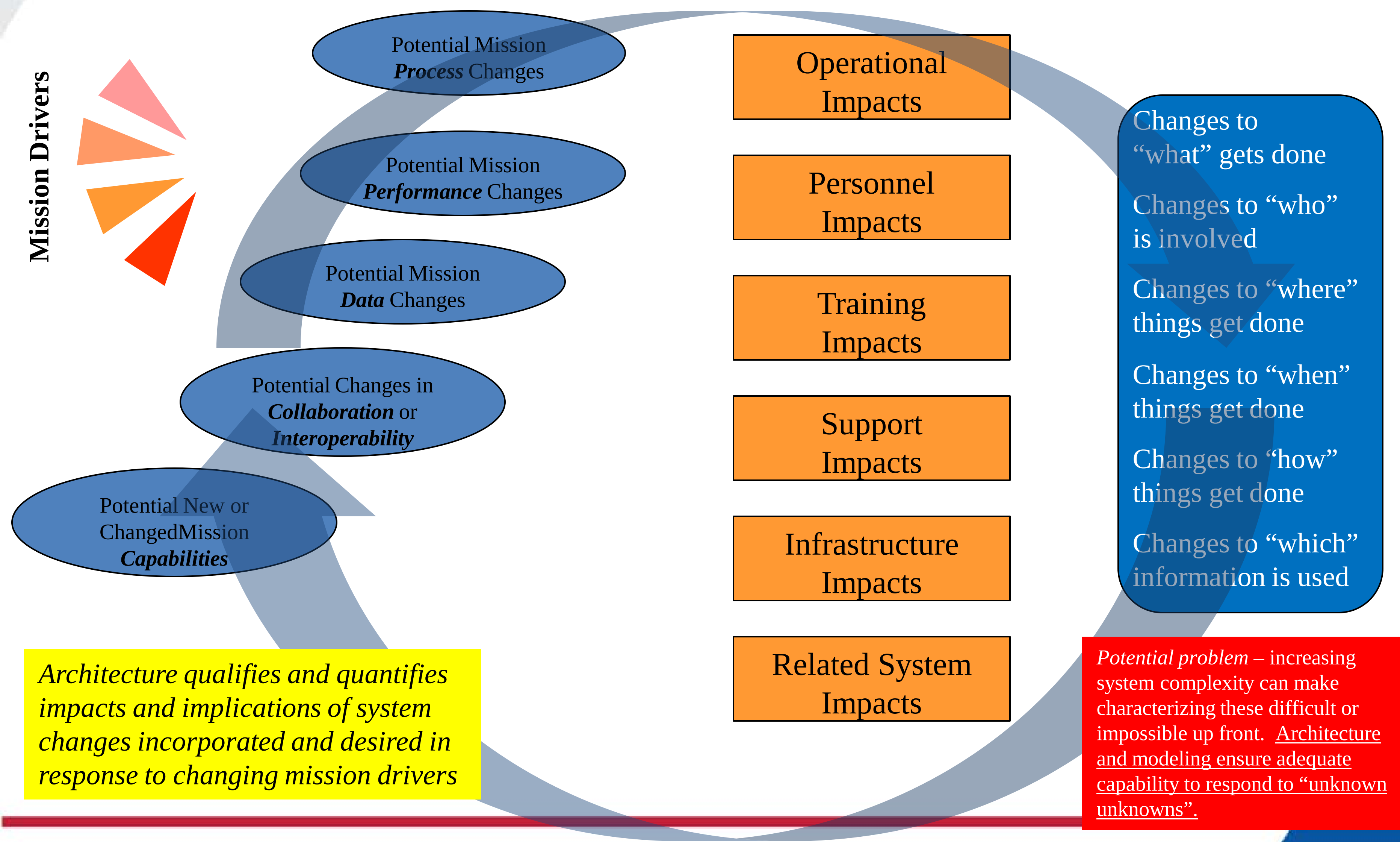
Systems Engineering & PM approach based on continuous modeling can address these factors simultaneously

Separate Needs vs. Requirements

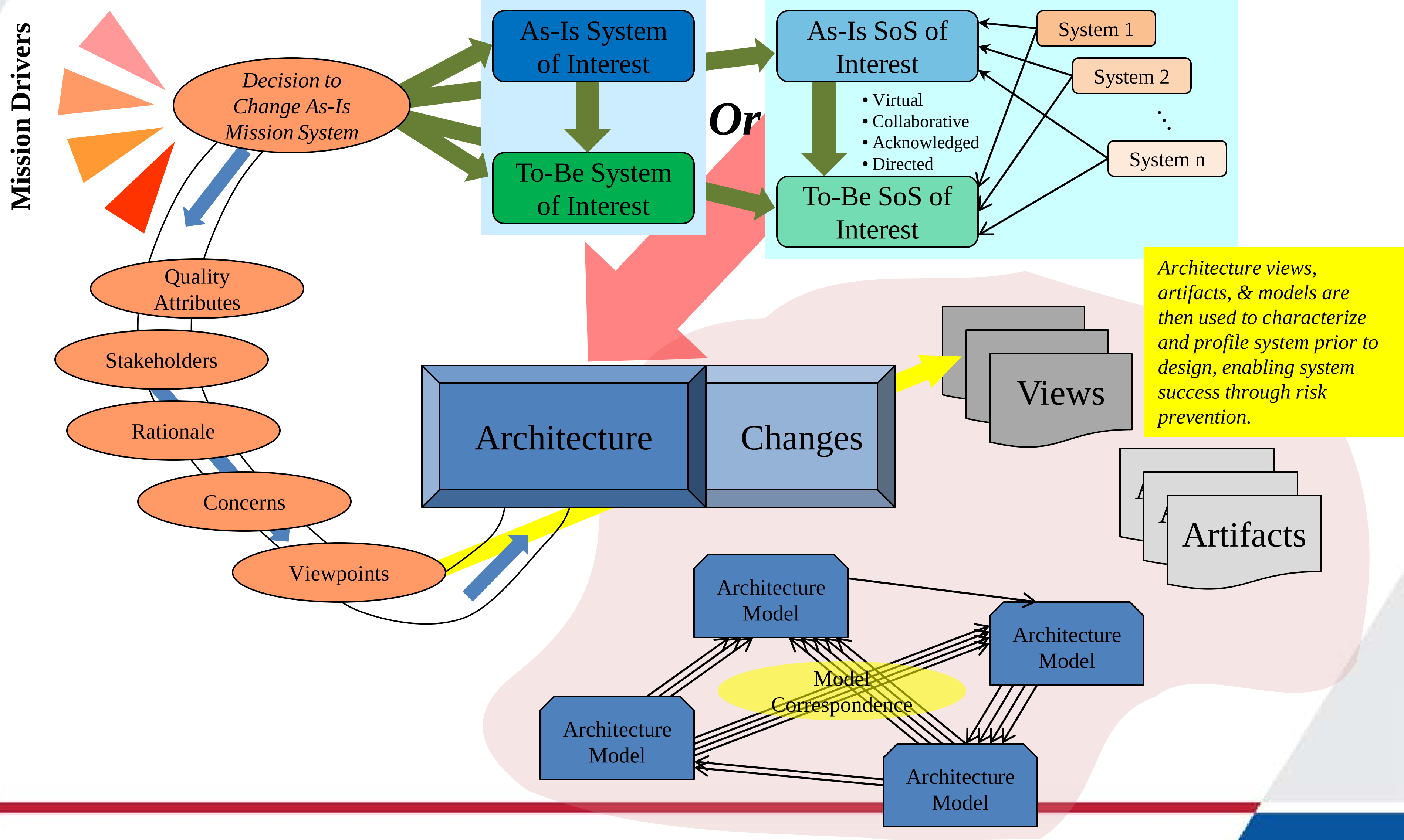


How much feedback, verification, and assurance activity is there to ensure that requirements as felt are actually implemented?
Very little.
Also, is any such activity structural? No.

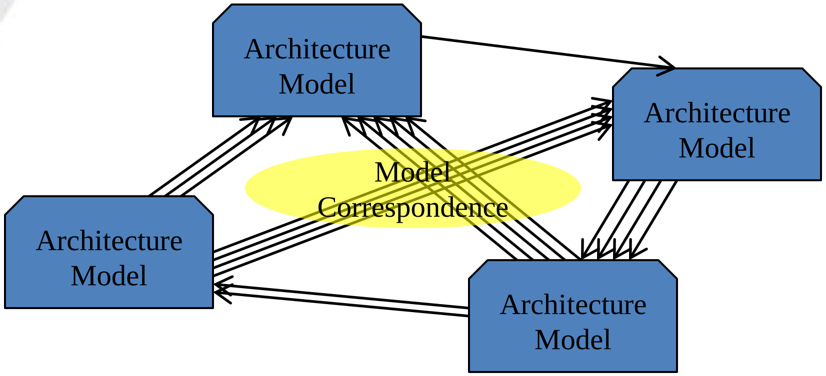
Need for Architecture Framework



Develop Architecture Framework



Perform Architecture Modeling

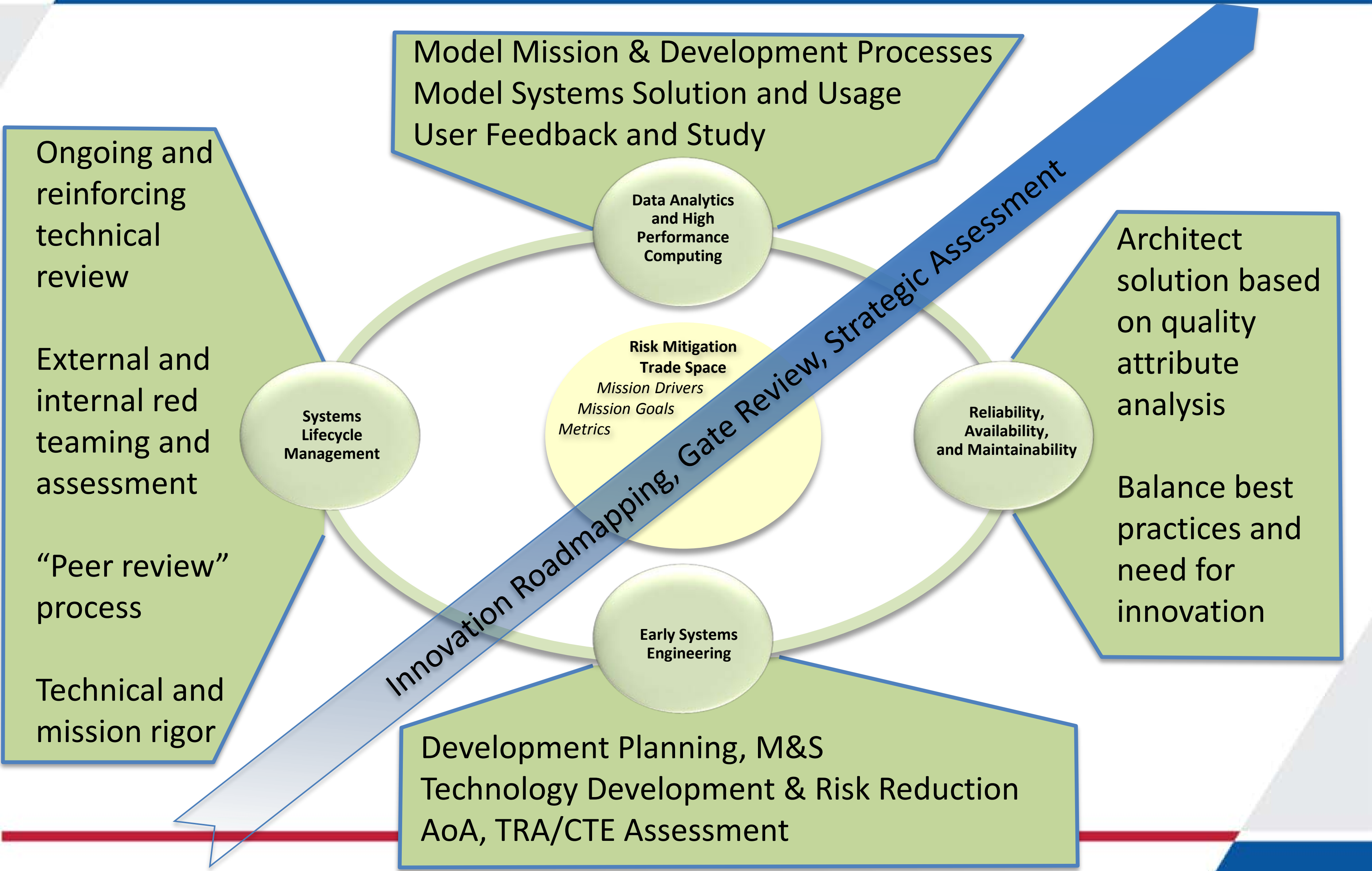


- Rigorous Identification & Evaluation of Assumptions and Constraints
- Pursue Early & Explicit Coupling of System Attributes, Aspects, and Factors
- Identification of Metadata and Context
- Establish Mutual Team Understanding and Shared Decision Making
- Identify Impacts and Implications
- Establish Adaptability and Flexibility to Handle Unknown and Emergent Properties

These modeling processes characterize and explore a system in human-friendly and knowledge-surfacing terms which enable system success.

- *Usage & Decision Modeling*
  - Concept Refinement Modeling
  - Operational Vignette Modeling
- *Technical Modeling*
  - Interface Specification & Modeling
  - Technology Modeling
  - Prototype Modeling
  - Emergent Properties Modeling
  - Testability Modeling
- *Program Modeling*
  - Requirements Modeling
  - Financial Scenarios & Sensitivity Analysis
  - EVM Criteria Modeling & Analysis
  - IMS/IMP Modeling
  - Risk Modeling & Prevention

Comprehensive SE Framework



CSEF and S&T/SE Integration

- Several dynamics are continuously at work in CSEF:
  - Inner cycle operates to identify and resolve S&T research imperatives and SE concerns in response to ongoing risk mitigation trades
  - Invention and innovation progress upwards and the to the right, seeking ongoing maximization of technical and programmatic criteria based on R&D and SE
  - Risk mitigation trade space accepts and resolves risk on an ongoing basis
- CSEF continuously facilitates the entry and maturation of projects on the Rogers Innovation curve
  - The CSEF concept strongly connects innovator, early adopter, early maturity and late maturity phases
  - This connection continuously identifies new candidates on the "lower left" of the curve, and matures technology for appropriate insertion into mission processes
  - Feedback into S&T and R&D is structured and ongoing through technical interchange, to ensure prioritization of research agenda and meaningful technical roadmapping

Continuous <u>innovation</u> matures and releases new and complex technology to the mission community in a timely, risk-reduced way

Continuous <u>invention</u> means the R&D community is continuously engaged to form and satisfy a research agenda based on evolving and dynamic mission requirements

Conclusion: Re-envisioning SE/PM as KM through CSEF

- Maximize involvement of agency in programs to *prevent* risk
  - Leverage expertise and build more reach-back to previous success
- SE/PM Research Agenda needed
  - Management concepts
  - Technical concepts
- Manage programs as socio-technical systems
- Focus on knowledge discovery, creation, structure, and use
- Focus on human capital
- Evolve acquisition incentives to value contractor knowledge

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